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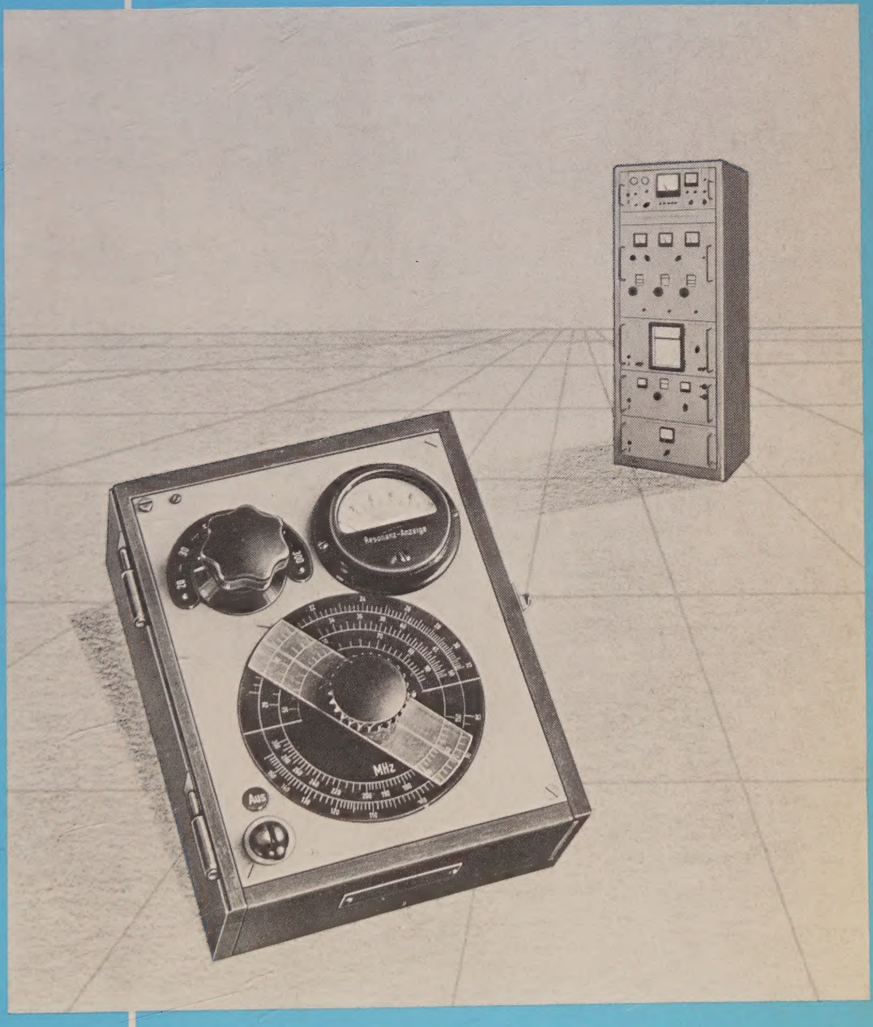

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ROHDE & SCHWARZ MÜNCHEN 8

Submitted by:

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The cover photograph shows the progress in the development of the R & S measuring instruments.

One of the first instruments built by R & S (in the foreground) is shown together with the modern Decade Frequency Measuring System Type XZA.

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Accuracy of the Precision Bridge Type LCB

Whenever the development of a new measuring instrument is completed, scruples arise for the manufacturer as to which accuracy he shall specify. It is not easy to answer this question, since the measurement error, even of such a simple instrument as a yardstick, normally is composed of several individual errors: the varying length of the stick – due to temperature changes, absorption of moisture, aging, suspension or support in the gravitational field – moreover, the width of the scale marks, the accuracy of the calibration device, the errors occurring in the comparison between the measuring stick and the item to be measured, etc. It can be imagined that it is much more difficult to estimate the possible errors of an electronic instrument, where many more sources of errors are involved. The specifications often become intricate if all error sources are indicated, whereas the range of application of an instrument may be reduced if the specifications of the errors are insufficient.

Unfortunately, even a development engineer experienced in the field of measuring instruments will often be unable to foresee all possibilities of application that will come up in practice. The error specifications given in data sheets and instruction books must, therefore, be supplemented continually by special information. The greatest measurement errors generally occur at the range limits, where measurements can be made if the sacrifice in accuracy is known.

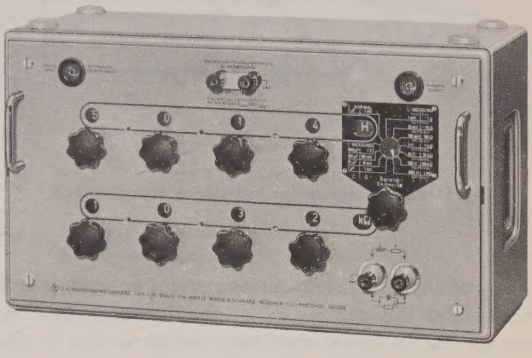
Since we have received quite a number of special enquiries concerning our **L-C Precision Bridge Type LCB,** this article is to give detailed error curves. Our L-C bridge permits the measurement of

a. Inductances in the range of from 10 μh to 1000 h and their equivalent loss resistances between 0.01 Ω and 1 MΩ,

b. Capacitances of from 0.01 μf to 1000 μf and their equivalent conductances between 10 μmhos and 1 mho

with AC voltages of from 50 cps to 20 kc. The inductances can be loaded and biassed with direct current during the measurement. Figs. 1 and 2 show the basic diagram of the bridge, Fig. 3 the simplified circuit diagram.

The accuracy of the bridge is mainly determined by the following factors:



Precision Bridge Type LCB

1. Accuracy of the decade capacitance standards C_N
2. Temperature dependence of the decade capacitance standards
3. Dissipation factor of the decade capacitance standards
4. Accuracy of the fixed and variable resistors R_1, R_2, G_N
5. Temperature dependence of the resistors
6. Aging of the depos. carbon resistors which make up part of the decade conductance element
7. Reactive components of the resistors
8. Step error (error due to the fact that the smallest decade is not continuously adjustable)
9. Capacitances, inductances and resistances of wiring and switches.

The error quantities of the nine above-listed types of errors are known from measurement and theory. The following error curves are calculated values which take account of all above errors in their most adverse combinations; in other words, the maximum possible errors are given, while the actual errors are in most cases smaller. The errors resulting from the calculation are complex errors. For this reason, the absolute errors plotted in the curves must not be used for a correction of the measured values. All representations are true for a temperature range of from + 10° to + 30° C.

Figs. 4 and 5 show the frequency-independent, maximum possible **error of the measured L and C values.** In some measurement ranges, the errors are also dependent on the value of the pure resistances of the test items, which is due to the unavoidable reactive components of the bridge resistors. The increase of the errors at the lower

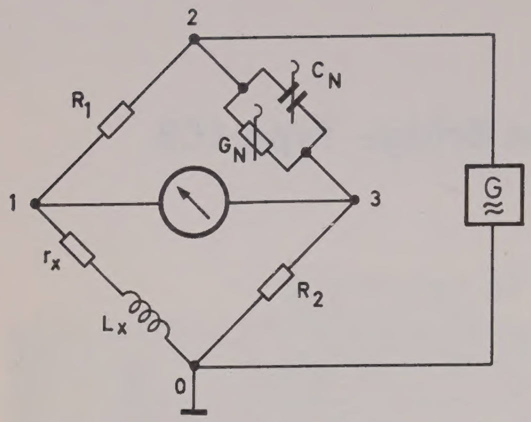


Fig. 1 Basic diagram for inductance measurements

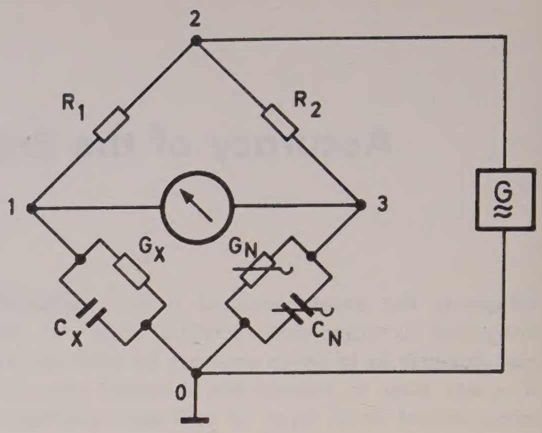


Fig. 2 Basic diagram for capacitance measurements

limits of the individual measurement ranges is not caused by the properties of the bridge elements, but by the so-called step error which is due to the fact that the smallest decade is not continuously adjustable. The error necessarily increases if the available 4 decades are not fully used for the measurement. For the calculation of the curves it has been assumed that half of the last step can still be estimated. In the most adverse case of a measurement in the 1-h range, for example, an inductance in the vicinity of 0.1 mh can be measured only with an accuracy of ± 50%. Consequently, it is of advantage to select the smallest possible measurement range to be able to exactly balance the bridge and thus to keep the step error small. For high-loss reactances this is not always possible, e. g., if the equivalent loss resistance or the equivalent conductance exceeds the maximum r or G value that can be balanced in the respective L or C range. The equivalent resistance r_x, for example, must not exceed ≈1.1 Ω in the 1-mh range, otherwise the measurement would have to be made in the next higher range. In the Type LCB accurately defined end values of the loss components are associated with the range-end values of the reactances:

1 mh:	1 Ω	1 µf:	1 mmho
10 mh:	10 Ω	10 µf:	10 mmhos
100 mh:	100 Ω	100 µf:	100 mmhos
1 h:	1 kΩ	1000 µf:	1 mho
10 h:	10 kΩ		
100 h:	100 kΩ		
1000 h:	1 MΩ		

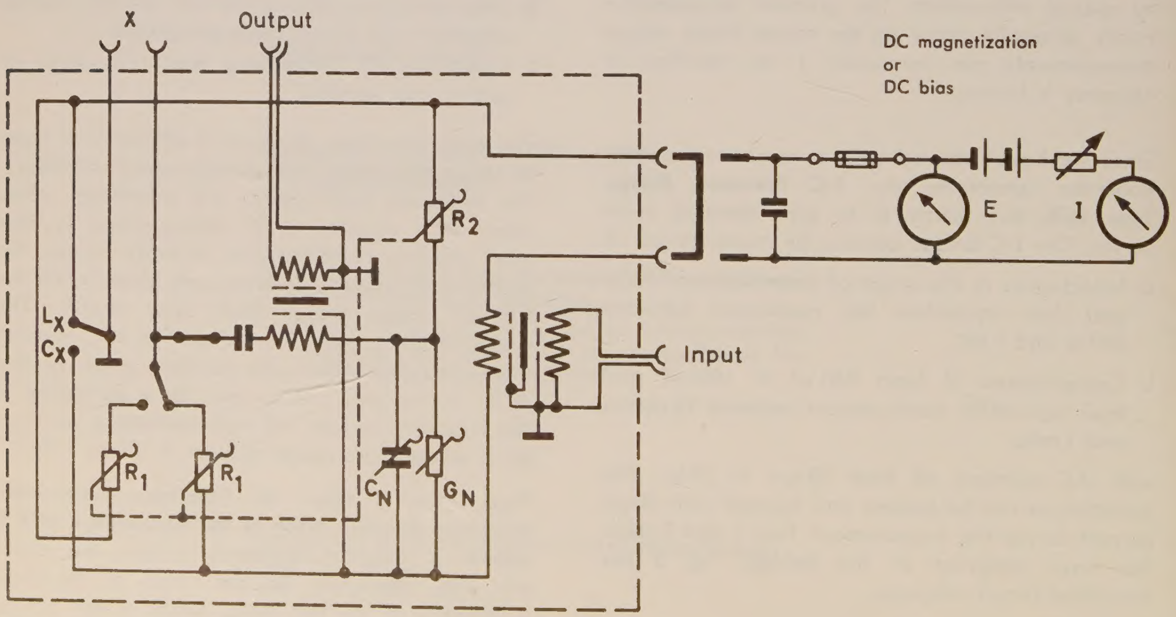


Fig. 3 Simplified diagram of the L-C Precision Bridge

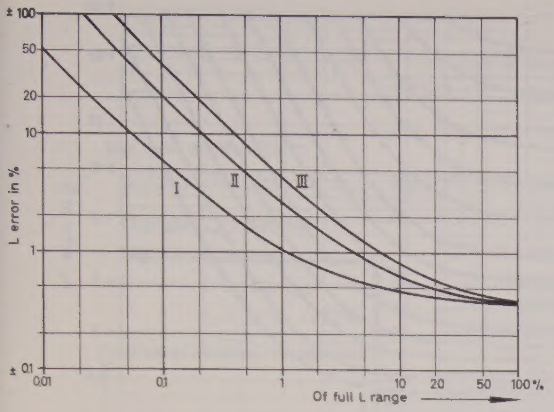


Fig. 4 Accuracy of the L measurement
Temperature range: + 10° – + 30° C

Curve I: Ranges 1 mh – 10 h hold for all r_x settings
Range 100 h holds for $r_x \leq$ 5 kΩ
Range 1000 h holds for $r_x \leq$ 50 kΩ

Curve II: Range 100 h holds for r_x = 100 kΩ
Range 1000 h holds for r_x = 500 kΩ

Curve III: Range 1000 h holds for r_x = 1 MΩ

The step error does, of course, not occur when an inductance or capacitance is adjusted to a value preset on the bridge. The error curves of Figs. 4 and 5 then are much flatter and have an error of only 0.6 % at 0.1 % of the full L or C range.

The **precision** with which **equivalent resistances or equivalent conductances** can be measured depends not only on the accuracy of the bridge resistors but also on their phase error, i. e. on the value of their reactive components as well as on the losses of the decade capacitors. The phase errors have only a negligible influence on the reactance measurement, whereas they greatly influence the determination of the resistive component of the test item. It is easy to recognize the influence of the dissipation factor of the capacitance decades, designated by C_N in Figs. 1 and 2, if one imagines the measurement of a lossless test item, where r_x or G_x is zero. The balancing conditions for the Type LCB are known as follows:

L range

$$L_x = R_1 \cdot R_2 \cdot C_N; \qquad r_x = R_1 \cdot R_2 \cdot G_N$$

C range

$$C_x = \frac{R_2}{R_1} \cdot C_N; \qquad G_x = \frac{R_2}{R_1} \cdot G_N$$

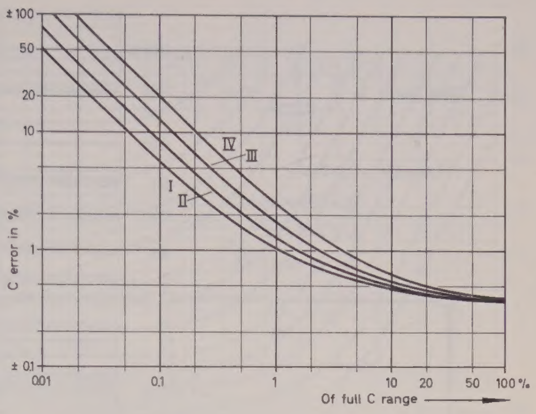


Fig. 5 Accuracy of the C measurement
Temperature range: + 10° – + 30° C

Curve I: Range 1 μf holds for all G_x settings
Range 10 μf holds for $G_x \leq$ 1 mmho
Range 100 μf holds for $G_x \leq$ 10 mmhos
Range 1000 μf holds for $G_x \leq$ 100 mmhos

Curve II: Range 10 μf holds for G_x = 10 mmhos
Range 100 μf holds for G_x = 20 mmhos
Range 1000 μf holds for G_x = 200 mmhos

Curve III: Range 100 μf holds for G_x = 50 mmhos
Range 1000 μf holds for G_x = 500 mmhos

Curve IV: Range 100 μf holds for $G_x \approx$ 100 mmhos
Range 1000 μf holds for $G_x \approx$ 1 mho

The bridge is balanced for $r_x = 0$ if $G_N = 0$. Due to the loss of the decade capacitor C_N, an additional conductance is in parallel to G_N, by the amount of which the measurements are in error. The dissipation factor of C_N is about 3 parts in 10^4, which corresponds to a Q of ≈ 3300. The equivalent series resistance of a coil having a Q of 30 would thus be measured with an error of about 1 %, that of a coil having a Q of 300 with an error of about 10 %. Since the dissipation factor of the C decades remains frequency-independent in the frequency range of the Type LCB the detrimental value of the conductance is proportional to the frequency and cannot be allowed for by calibration.

It can be proved that the errors which are caused by the dissipation factor of the capacitors and those which are caused by the reactive components of the bridge resistors have opposite signs, provided R_1 has an inductive and R_2 a capacitive component. By suitable design of the Type LCB it has been possible by compensation to decrease the errors considerably over a wide frequency range in the L ranges 1 mh to 10 h. In the other L ranges, the reactive component of R_1 is always capacitive, so that this measure could not be

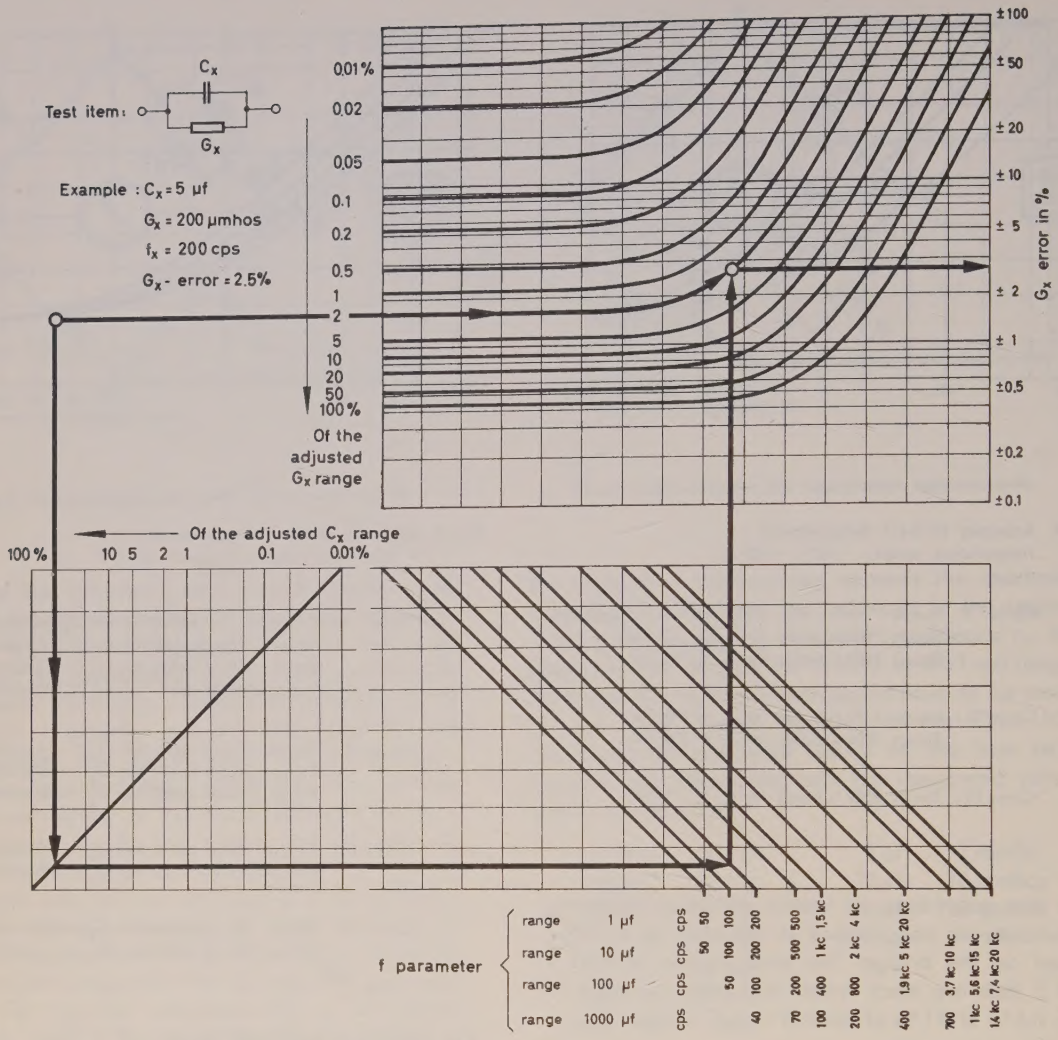


Fig. 6 r_x error in inductance measurements

Frequency Table (Frequencies indicated in kc)

Curve No.	Ranges 1 and 10 mh			Range 100 mh			Range 1 h			Range 10 h			Range 100 h	Range 1000 h
1	—	—	—	—	—	—	—	—	—	—	—	—	0.06	0.05
2	—	—	—	—	—	—	—	—	—	—	—	—	0.122	0.10
3	0.05	9.95	10.05	0.05	4.95	5.05	0.05	2.95	3.05	0.05	0.95	1.05	0.155	0.126
4	0.10	9.9	10.1	0.10	4.9	5.1	0.10	2.9	3.1	0.11	0.90	1.1	0.217	0.177
5	0.20	9.8	10.2	0.20	4.8	5.2	0.20	2.8	3.2	0.27	0.73	1.17	0.306	0.25
6	0.50	9.5	10.5	0.53	4.5	5.5	0.60	2.4	3.4	0.50		—	0.476	0.39
7	1	9	11	—	—	—	1.5		—	—	—	1.35	0.656	0.536
8	2	8	11.5	2.5		—	—	—	4.2	—	—	—	0.875	0.714
9	5		12	—	—	6.8	—	—	4.5	—	—	2	1.0	0.892
10	—	—	15	—	—	9.1	—	—	5.0	—	—	3.3	1.9	1.5
11	—	—	20	—	—	13.1	—	—	7.1	—	—	5.0	3.1	2.5
12	—	—	—	—	—	20	—	—	17.0	—	—	9.5	6.1	5
13	—	—	—	—	—	—	—	—	—	—	—	18.4	12.2	10

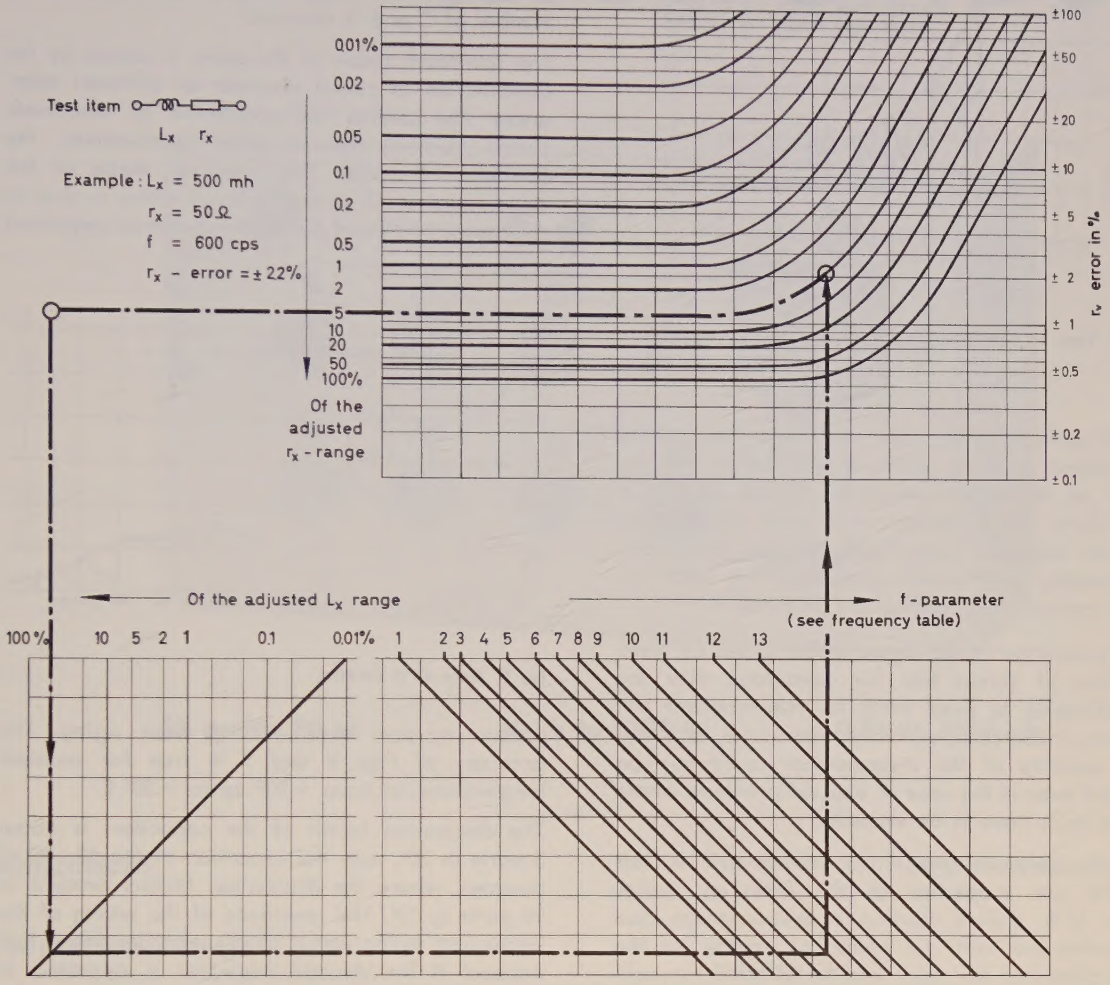


Fig. 7 G_x error in capacitance measurements

employed here. In the C ranges, the compensation is not possible either.

Fig. 6 gives a graphic representation of the accuracy for the measurement of the equivalent series resistances r_x of coils, while Fig. 7 shows the accuracy of the equivalent conductances G_x of capacitors. The relations are very complicated, since the error depends on frequency, measurement range, reactive and resistive components of the test item. The use of the diagrams can best be explained with the aid of an example. The Type LCB is used to measure a coil at 600 cps. The indicated values are: $L_x = 500$ mh and $r_x = 50\ \Omega$. What is the error of this measurement? In the 1-h range, 500 mh are 50 % of the range-end value. Therefore, find the value 50 % on the L_x axis, draw a perpendicular from there to the oblique straight line and a horizontal from the point of intersection to the family of straight lines in the lower right field. The individual straight lines are numbered, their association with the frequency can be taken from the attached table. Three frequencies have been associated with some of the straight lines in the ranges 1 mh to 10 h, due to the compensation of the dissipation factor of the C_N decades against the phase error of the resistors. The error first increases with the frequency, reaches a maximum at half the compensation frequency $^1/_2$ f_0, decreases to a minimum at f_0, and increases again. In the other ranges, the error increases uniformly with the frequency; only one frequency corresponds to each straight line. The straight line No. 6 belongs to the frequency f = 600 cps in the range 1 h. Draw a perpendicular from the point of intersection of the horizontal with this straight line and extend this perpendicular to the family of curves of the upper field. Equivalent resistances of up to 1 kΩ (nominal value of the range) can be measured in the 1-h range. The equivalent resistance of the coil in our example is 50 Ω, which corresponds to 5 % of the range-end value. Now, find in the upper field the r_x parameter 5 % and follow the associated curve to the intersection with the perpendicular

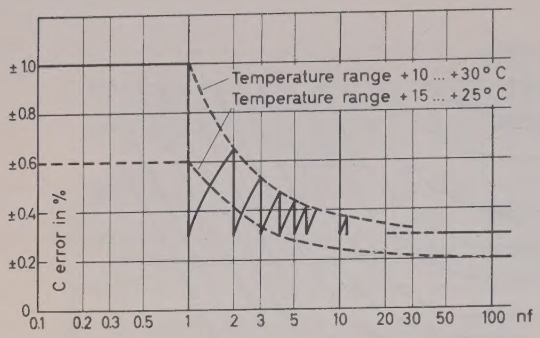


Fig. 8 Error of C decades

which comes from the lower right field. The r_x error associated with the point of intersection can be read on the right-hand scale; in our case it is $\approx \pm 2.2\,\%$. The L_x value has an error of $\pm 0.36\,\%$, as can be seen from Fig. 4. Proceed in a corresponding way, when calculating the error for lossy capacitors according to Figs. 5 and 7.

Representation of the measurement errors by these families of curves has the advantage over the specification of fixed limits for measurement frequency, inductance, equivalent resistance, etc., that the usability of the measurement result can be judged even in the case of unusual problems where these limits have to be exceeded.

All the measurement errors represented in this article are properties of the Precision Bridge Type LCB. Before starting a measurement, due consideration must be given, of course, to the possibility that the result may be affected by properties of the test item itself, properties which actually should not enter into the measurement. When measuring coils and transformers, for example, care should be taken not to select too high a measurement frequency, in order to prevent the winding capacitance from having an influence. An article, which will be published later, will give a detailed description of these and other error sources which exclusively depend on the test item.

To make the Type LCB as versatile as possible, the decade capacitor C_N and the decade conductance element G_N are usable as standards in a special position of the range switch, the rest of the bridge circuit then being disconnected. Figs. 8 and 9 show the accuracy of the decades. The curves show two marked characteristics: The increase in errors with decreasing C_N and G_N values and the saw-tooth shape.

Fundamentally, it would have been possible to equip all decades with circuit elements of the same accuracy. For the use as test bridge, however, it would not have been worth-while to make the error of the capacitors and resistors for the small decade steps much smaller than the step error already mentioned. This error, which appears with test items having about $^1/_{10}$ of the nominal value of the respective measurement range, is nearly unvarying with most test items, due to the given number of C and G decades.

The saw-tooth shape of the curve is caused by the combination of circuit elements of different tolerances. The smaller the proportion of inaccurate circuit elements for a given combination, the smaller is its error. The irregular shape of the error curve of G values below 1 µmho is due to the characteristics of the high-impedance deposited carbon resistors used and to their aging. The accuracy of Figs. 8 and 9 is true for ambient temperatures of from + 10° up to + 30° C.

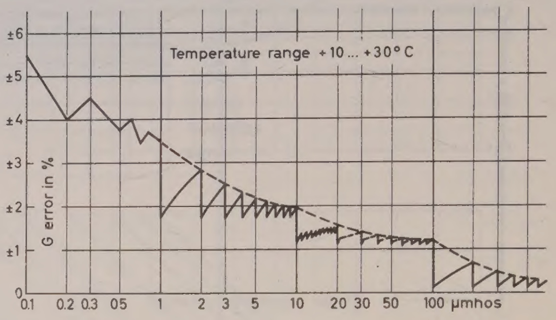


Fig. 9 Error of G decades

The dissipation factor of the capacitors is about 3 parts in 10^4, with the exception of the 12 x 0.1 nf decades, where the dissipation factors amount to 10 parts in 10^4. The resistance of the wiring of the instrument, being about 20 mΩ, must be taken into account if the decade capacitor is operated at frequencies above 500 cps. At 1 kc, for example, the aforementioned 20 mΩ give an additional dissipation factor as high as 1 part in 10^4.

The wiring inductance, which amounts to about 0.45 µh, can be neglected in the consideration of the errors, provided the measurements are made at low frequencies.

Summary

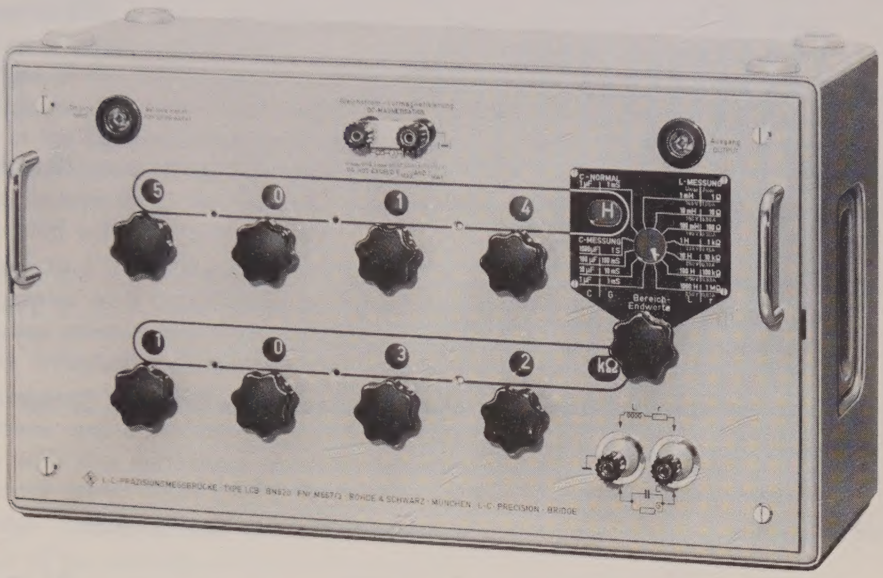
To enable the user of our Precision Bridge Type LCB to estimate the errors when measurements are made beyond the limits given in the data sheet, all individual errors have been added up and represented graphically. It is found that the errors are frequency-independent in inductance and capacitance measurements, while the measurement of the resistive components depends on quite a number of parameters, which may cause considerable errors at high frequencies.

All error curves published are short abstracts from the latest instruction book for the Type LCB.

G. Dabrowski

Type **LCB**

L-C PRECISION BRIDGE



50 cps to 20 kc **10 μh to 1000 h** **0.01 to 1000 μf**

Specifications

►Order Number BN 620

Use as Inductance Bridge

The item under test is measured as an ideal inductor in series with a pure resistance.

inductance range

up to 20 kc	10 μh to 10 mh
up to 5 kc	to 100 mh
up to 3 kc	to 1 h
up to 300 cps	to 10 h
up to 100 cps	to 100 h
at 50 cps	to 1000 h

Resistance range	0.01 Ω to 1 MΩ

Accuracy

Inductance (L)	± 0.3% ± 0.1 μh
Series resistance (R)	± 3% ± 1 milliΩ
Dissipation factor ($\tan\delta = \frac{R}{\omega L}$)	$\pm 10^{-3}$

In the range 1000 h, the specified accuracy values increase by the factor of 2; that of the dissipation factor goes up to $\pm 10^{-2}$.
D-c magnetization of the item under test is possible.

Printed in Germany

Use as Capacitance Bridge

The item under test is measured as an ideal capacitor in parallel with a pure conductance.

Capacitance range

up to 20 kc	0.01 to 1 μf
up to 1.5 kc	to 10 μf
up to 150 cps	to 100 μf
at 50 cps	to 1000 μf

Conductance range	10 μmhos to 1 mho

Accuracy

Capacitance (C)	± 0.3% ± 100 μμf
Conductance (G)	± 3% ± 0.1 μmho
Dissipation factor ($\tan\delta = \frac{G}{\omega C}$)	± 10^{-3}

In the range 1000 μf, the specified accuracy values increase by the factor of 2; that of the dissipation factor goes up to ± 10^{-2}.

Use as Decade Capacitor

Range	100 μμf to 1 μf
adjustable in four decades	11 x 100 μμf 11 x 1000 μμf 11 x 10,000 μμf 11 x 100,000 μμf
Accuracy	± 0.2% ± 30 μμf
Dielectric	polystyrene

Use as Decade Conductance

Range	0.1 to 1000 μmhos
adjustable in four decades	11 x 0.1 μmho 11 x 1 μmho 11 x 10 μmhos 11 x 100 μmhos
Accuracy	± 0.3 to ± 5% depending on range

The capacitance and conductance components are parallel-connected so that any capacitive impedance can be simulated in the specified ranges.

Other Data

Connector for item under test	knurled terminals with provision for banana plugs
Input for bridge supply	coaxial 13-mm socket
Input inpedance	10 Ω to 1 kΩ
Input voltage	4 v max. at 50 cps, 30 v max. at 20 kc
Bridge output socket	coaxial 13-mm socket
Output impedance	2 to 10 kΩ
Dimensions	470 x 275 x 260 mm (R&S Standard Cabinet 46)
Weight	12 kg

Additional Equipment Required

Oscillator with fixed or variable frequency in the range 50 cps to 20 kc; e.g. the R&S Oscillator 800/1,000 cps Type STK BN 4014 (800 and 1000 cps) or R&S RC Generator Type SRM BN 4085 (30 cps to 300 kc) .

Amplifier-voltmeter for frequencies corresponding with those of the oscillator, preferably tunable. Sensitivity equal to or better than 50 μv; e. g. R&S Tunable Indicating Amplifier Type UBM BN 12121/2, 45 cps to 600 kc, tunable and broadband, sensitivity 3 μv, logarithmic indication.

Uses

The rapid and accurate measurement of the inductance of chokes, transformers, etc. is often difficult even in well equipped laboratories. Here, the L-C Precision Bridge Type LCB fills a gap. Very accurate and easy to operate, it offers both possibilities at the same time.

The L-C Precision Bridge Type LCB is mainly designed for inductance measurements. The inductance range extends up to 1000 henrys, permitting even unusual measurements to be made. The item under test is measured as a series circuit made up of an ideal inductance and a pure resistance. After bridge balancing the values of the inductance and of the resistance are separately available as direct readings. Hence it is possible to determine lossy inductances as well as impedances with inductive components. This is important in the determination of the time constant of wire-wound resistors where resonance methods usually are inadequate. Direct current may be applied to the test item during the test, if necessary. This is a desirable feature if the measurement is to be made on a transformer which under actual working conditions is operated with d-c magnetization.

Inductance measurement is not the only application of this bridge. After changeover of the range switch, the instrument operates as a capacitance bridge. Importance has been attached to ensure that high capacitance values are measurable. The active and reactive components are again read separately and directly, just as in inductance measurements.

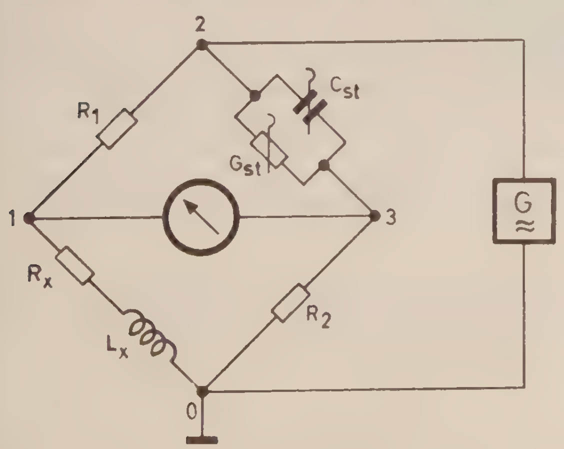
The obtainable accuracy is so high and the frequency range so large that all measurements falling in the given inductance and capacitance ranges can be made. Inductance or capacitance values smaller than measurable with this instrument can be measured with the R&S Inductance Meter Type LARU or the R&S Capacitance Meter Type KARU. These instruments operate at higher frequencies, whereas the L-C Precision Bridge Type LCB has been designed for measurements in the audio-frequency range.

Multiple utilization of the precision components contained in the L-C Precision Bridge Type LCB is possible. Most of the built-in capacitors and resistors are accessible via the test sockets, when the range switch is set at a separate position. Thus this instrument can also be used as a decade capacitance or conductance.

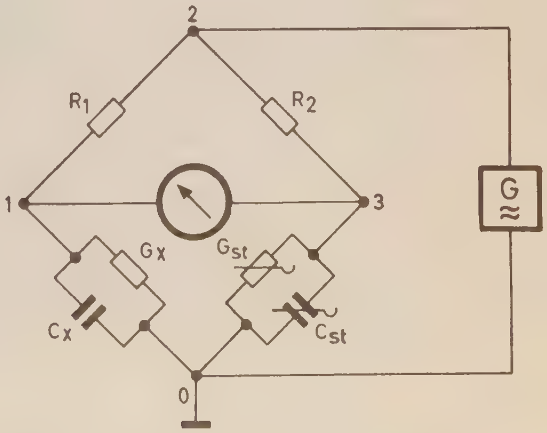
The great number of switching possibilities is justified only when errors are not easily committed thereby. Simplicity of operation has been ensured by suitable layout and design of the operating controls. The readings or decade settings are given as a figure including decimal point and dimensions. It is not necessary to make any calculations to obtain the results.

Description

The L-C Precision Bridge Type LCB operates as a Maxwell bridge in inductance measurement and as a Wheatstone bridge in capacitance measurement. A common pair of terminals serves as connector to the test item in bridge measurements and when the instrument is used as a decade capacitance or conductance. The L-C precision bridge is housed in an R&S Standard Steel Cabinet 46 (front panel size 450 x 239 mm). The cabinet can be replaced by a dust cover when the instrument is to be rack mounted in an R&S Test Rack 450 or in a Standard Rack 520 built to German Standard DIN 41491. In the latter case, it is necessary to use a suitable mounting plate.



Simplified circuit diagram of the LCB used as an inductance bridge



Simplified circuit diagram of the LCB used as a capacitance bridge

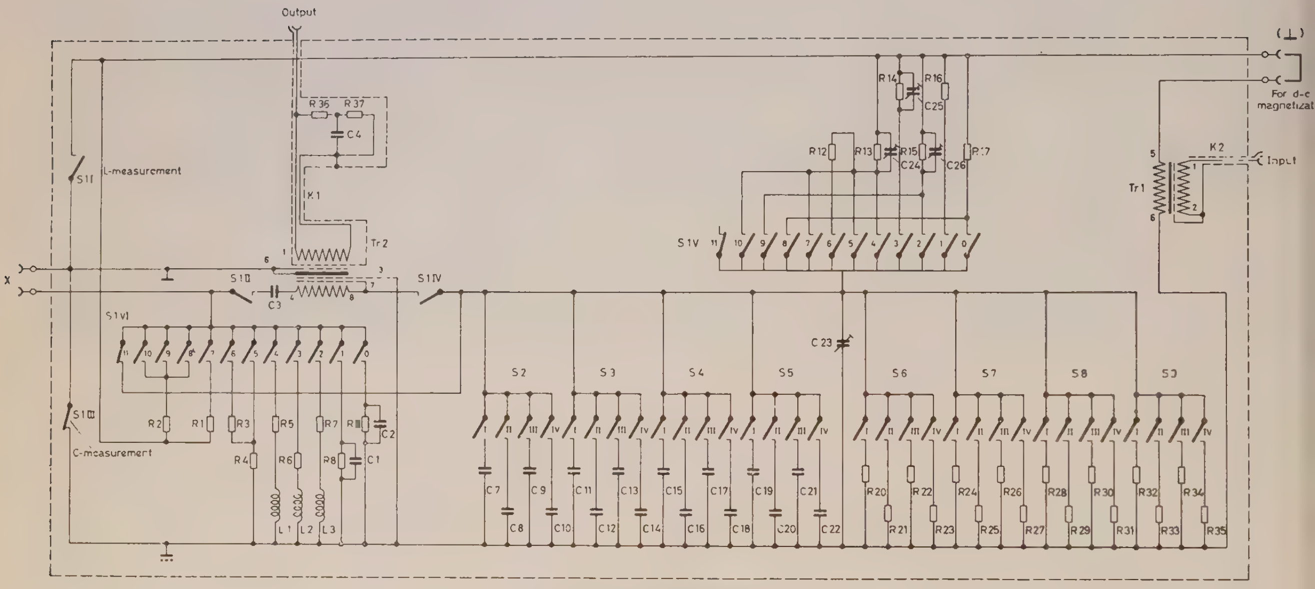
L-C PRECISION BRIDGE LCB

The balance conditions in use of the instrument as an inductance bridge are:

$$L_X = R_1 \cdot R_2 \cdot C_{st} \qquad \text{and} \qquad R_X = R_1 \cdot R_2 \cdot G_{st}$$

The balance conditions in use as a capacitance bridge are:

$$C_X = C_{st} \cdot \frac{R_2}{R_1} \qquad \text{and} \qquad G_X = G_{st} \cdot \frac{R_2}{R_1}$$



⊥ Common isolated from chassis

	S1				S2 S4				S5+). S9			
	I	II	III	IV	I	II	III	IV	I	II	III	IV
0	●	●		●								
1	●	●		●	●				●			
2	●	●		●		●				●		
3	●	●		●	●	●			●	●		
4	●	●		●	●		●		●		●	
5	●	●		●		●	●			●	●	
6	●	●		●	●	●	●		●	●	●	
7		●	●	●			●	●		●		●
8		●	●	●	●		●	●	●	●		●
9		●	●	●		●	●	●	●		●	●
10		●	●	●	●	●	●	●		●	●	●
11			●						●	●	●	●

+)For S5 holds
1 instead of 0
2 " 1
3 " 2
. .
12 instead of 11

Circuit diagram of the L-C Precision Bridge Type LCB BN 620

We reserve the right to make any departures from this specification, especially those considered desirable for reasons of improved design.

Providing a Synchronizing Input for the RC Oscillator of the Wide-Band Signal Generator Type SBF

The Wide-Band Signal Generator Type SBF BN 40861 features wide frequency and voltage ranges (10 cps to 10 Mc, 0.1 µv to 10 v), high stability and low distortion. It is mainly used in video and carrier-frequency engineering. The heart of the instrument is a wide-band amplifier above 100 kc driven by an LC oscillator, below 100 kc driven by an RC oscillator. Theoretically, the RC oscillator can easily be synchronized. However, at high frequencies the synchronizing lead would couple out so much RF energy that it would no longer be possible to produce accurately-known small output voltages with the Type SBF, unless complicated buffer stages were provided. For economical reasons, a synchronizing input has, therefore, not been provided in the signal generator.

The insertion of a synchronizing circuit for the RC oscillator, i. e. for the lower part of the frequency band, 10 cps to 100 kc, is described here to meet special requirements.

The modification is relatively simple. No measuring instruments or adjustments are necessary. The external synchronizing voltage is applied via a low-pass filter to the grid of the second stage of the RC oscillator. The necessary additional components are shown in heavy lines in Fig. 1. Connect the 10-kΩ resistor "a" in series to the grid-leak resistor R 31 (200 kΩ) of Rö 4 (EF 80). It is used to apply the external sync voltage and serves as terminating resistor for the low-pass filter. This filter is comprised of three T-half sections with the inductances "f" (5 mh) and "g" (10 mh), the capacitor "d" (400 pf) and the feed-through capacitor "e" (200 pf), and prevents RF leakage in operation of the signal generator above 100 kc. An MP capacitor "c" (2 µf) inserted between the input socket and the low-pass filter provides for DC isolation. The resistor "b" (500 kΩ) serves as discharge resistance.

This arrangement permits the oscillator frequency to be attracted by ± 0.4 % per 1 volt rms of synchronizing voltage. If the synchronizing voltage is heavily distorted, the Type SBF may be synchronized with the fundamental or with the harmonics. Since the distortion of the output voltage increases only slightly, the Type SBF may consequently be used to transform distorted waves into sinusoidal voltages. Even when a square-wave signal is used for synchronization the distortion factor increases by only 0.1 % / v_{pp}, which means an increase in distortion by 0.7 % for 7 v_{pp} (pull-in range 1 %). The output voltage of the Wide-Band Signal Generator Type SBF remains constant at the value adjusted for, independently of the synchronizing voltage.

Wide-Band Signal Generator Type SBF

Instructions for Mounting, R 7556

1. Disconnect the signal generator from the AC supply and remove the four cheese-head screws in the corners of the front panel. Remove the chassis from the steel cabinet and place it upside down on the work bench. After removing the bottom screws, the bottom panel can be opened. When the front panel looks towards the operator, the oscillator is to the right and the shielded output attenuator to the left within the aluminium casing (Fig. 2).

2. Drill a hole of 5.2 mm diameter in the wall of the casing in the direction of the front panel, at a distance of 80 mm from the right-hand inner edge of the casing and about 18 mm below the edge. Take care to remove all chips.

3. Fix the feed-through capacitor "e" (200 pf) in the hole with the nut looking outwards. Put a soldering lug below the nut.

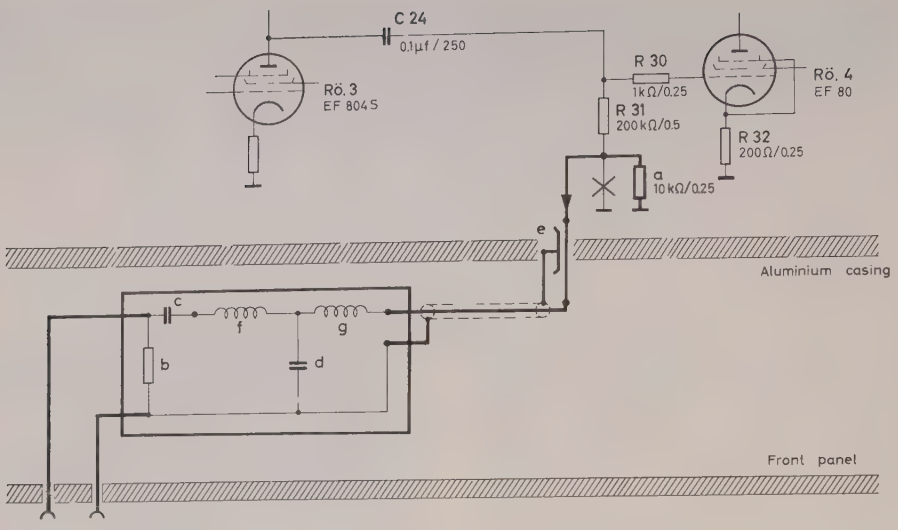


Fig. 1 Circuit diagram of synchronizing input

4. Drill two holes of 3.2 mm diameter 18 mm below the edge of the casing, at distances of 185 and 225 mm from the right-hand inner edge of the casing (Fig. 2). These holes serve for fixing the low-pass filter.

5. Make two holes for insulated telephone jacks in the front panel, for the synchronizing input. These holes are best made below the meter between the AMPLIFIER INPUT LEVEL switch and the VOLTAGE CONTROL knob. The spacing between these two holes is 19 mm. If the telephone jacks FD 804 are used, a diameter of 7.1 mm is required for the holes.

6. Mount the low-pass filter on a panel of insulating material, e. g. Superpertinax HP IV, and make the wiring. The dimensions of the panel are given in Fig. 3. The arrangement of the elements is shown in Fig. 4. Fix the capacitor "c" with a clip CZ 47/18 and stick the bobbins on the base panel. Make the wiring of the assembly according to Fig. 1.

7. Mount the insulator panel vertically between the casing and the front panel using two cheese-head screws M 3 x 25 DIN 84 and two spacers of 12 mm length. The two 3.2-mm holes previously made serve this purpose.

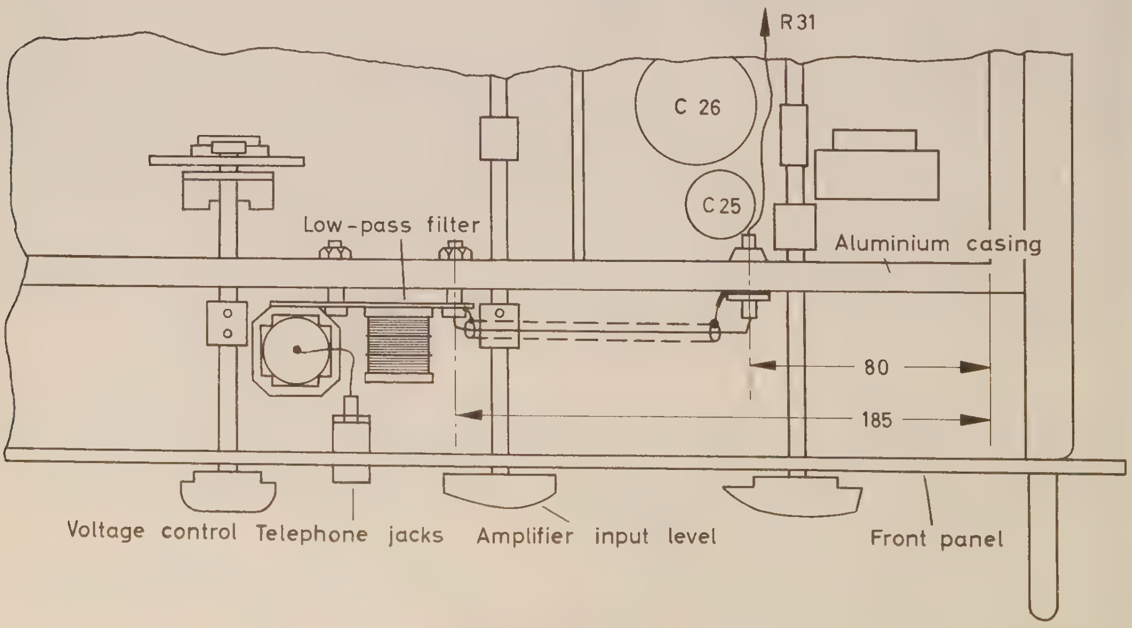


Fig. 2 Bottom view

8. Connect one of the front-panel jacks to the capacitor "c" (2 µf) and the other jack to the chassis-connected soldering lug of the insulator panel (Figs. 1 and 4). Run a shielded line from the insulator panel to the feed-through capacitor "e". Connect the shielding to the soldering lug (below the nut).

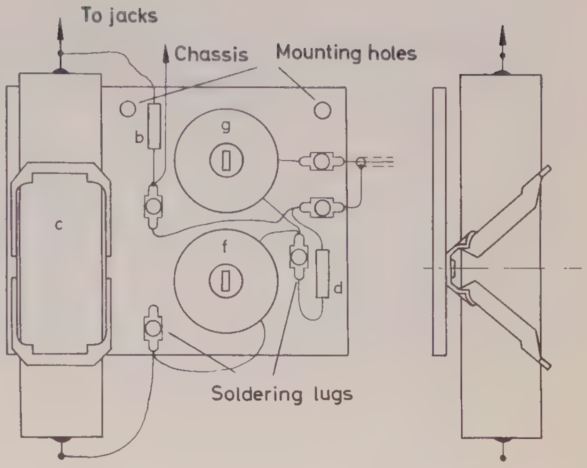


Fig. 4 Low-pass filter

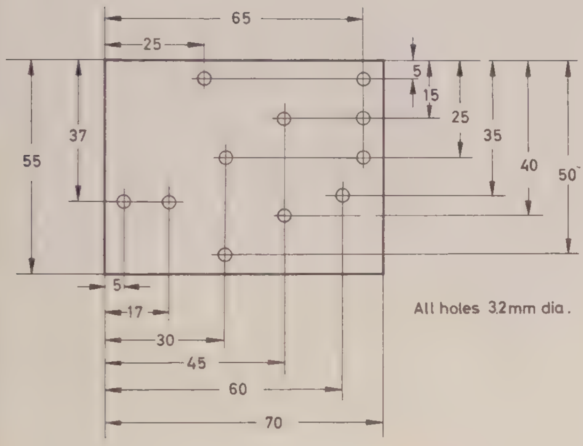


Fig. 3 Insulator panel for low-pass filter

Separate the 200-kΩ resistor R 31 in the circuit of the RC oscillator from chassis and solder it to the nearby vacant soldering lug. From this lug, connect the additional resistor "a" (10 kΩ) to chassis and an insulated wire to the feed-through capacitor. This completes the modification. Screw the bottom panel in place and put the chassis back into the cabinet.

The modification set, supplied by R & S under No. R 7556, consists of the following parts:

			R & S designation
1 resistor, depos. carbon	a	10 kΩ, 0.25 w	WF 10 K/0,25
1 resistor, depos. carbon	b	500 kΩ, 0.25 w	WF 500 K/0,25
1 capacitor, MP	c	2 µf/250 v	CMR 2/250
1 capacitor, synth. foil	d	400 pf	CKD 2/400/500
1 capacitor, feed-through	e	200 pf	CFR 2/200
1 bobbin for inductance	f	bobbin Type 3 H made by Neosid, 5 mh ± 10 % 411 windings, 137 windings per slot, CuL 0.27 mm dia.	Kern MM 064/3
1 bobbin for inductance	g	bobbin Type 3 H made by Neosid, 10 mh ± 10 % 582 windings, 194 windings per slot, CuL 0.22 mm dia.	Kern MM 064/3
1 clip for capacitor "c"			CZ 47/18
2 telephone jacks			FD 804
2 spacers, 12 mm in length			ZXD 11011/12

The modification set does not include the insulator panel, the soldering lugs, and the shielded cable. The bobbins for the inductances are not provided with windings.

Matuschek

R&S Instruments for AF and RF Measurements

A general survey of the measuring instruments made by ROHDE & SCHWARZ is given in No. 1 of the "Kurzinformation". Here and in the following issues the instruments for the measurements of **voltages** and **waveforms** will be discussed in more detail.

The complete field of voltage measurements is very extensive. An enormous number of methods have been developed and instruments designed for measuring AF and RF voltages. The most commonly known methods shall be explained briefly:

1. Instruments for voltage measurements only are the static voltmeters; among these, the two-filament electrometers are frequently used as reference meters. The attracting and repulsing forces are used for the indication of electric charges. The accurate rms value is indicated.
2. The voltage measurement using cathode-ray tubes is also based on a static method. Here the forces exerted by electric or magnetic fields on moving electrons are utilized.
3. A standard method consists in measuring the current which the voltage to be measured causes to flow in a known resistance. Moving-coil meters with rectifiers or thermo-couples are mainly used for indication. The thermo-coupled instruments indicate the rms value of the voltage. Generally this group of instruments does not present a very high input impedance.
4. The voltage measurement with rectifiers (valve voltmeters) has been developed to high perfection by R & S. A distinction may be made between flat-response voltmeters with and without preamplification and selective voltmeters. High input impedances are here obtained as in the instruments described in 1. and 2.

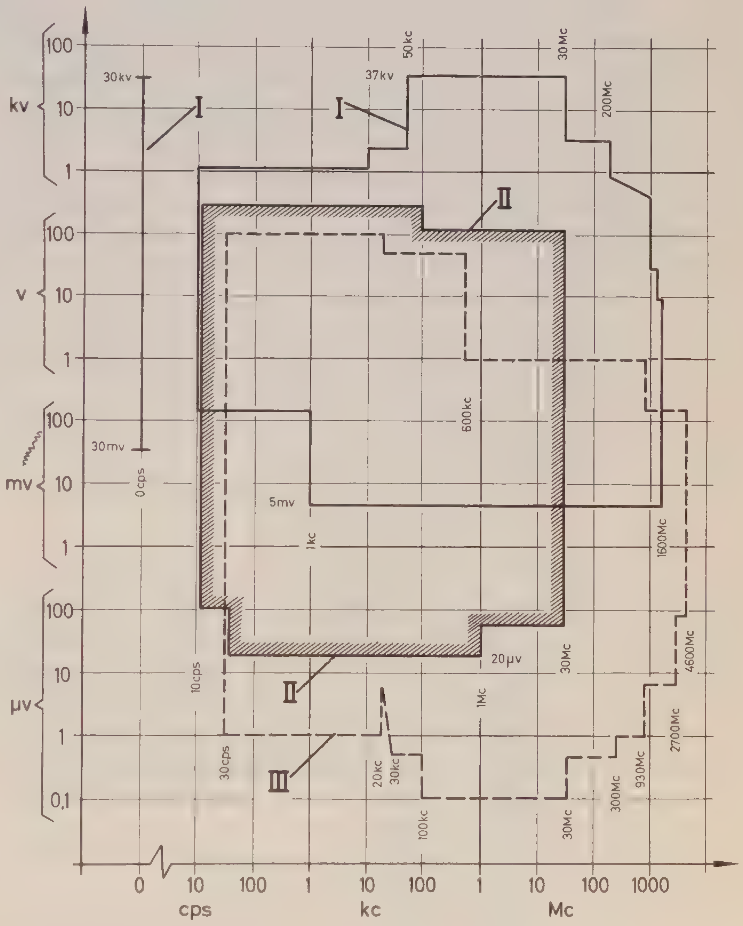


Fig. 1 Voltage and frequency ranges of all R & S voltmeters

Area I: all valve voltmeters without preamplification
Area II: all valve voltmeters with preamplification
Area III: all selective voltmeters

Considerable bandwidth is inherent in the **voltmeters without preamplification** since the behaviour of the rectifiers alone determines the frequency limits. The lower voltage limit is hardly below 10 to 100 mv. **With preamplification** (amplifier-rectifier types), the measurement range can be extended downward by about 3 powers of ten. An unavoidable result of preamplification is a considerable reduction of the frequency band, viz. to the 10th or 100th part. Because of the relatively high noise voltage present in broadband amplifiers it will hardly be possible to measure voltages below 10 to 100 µv. High sensitivity down to about 0.1 to 1 µv is obtainable in all frequency ranges with **selective voltmeters.**

ROHDE & SCHWARZ make five flat-response voltmeters without preamplification. Their frequency and voltage ranges are shown in Fig. 1 as area I. The frequency range is 10 cps to 1600 Mc, the lower voltage limit is 5 mv. Four voltmeters, again of the flat-response but amplifier-rectifier type, exhibit much greater sensitivity, namely down to about 20 μv. The frequency range is limited to 10 cps – 30 Mc as marked by area II. Valuable instruments meeting very stringent requirements are the selective voltmeters. A great number of types have been developed because of the great variety of problems encountered. They reach from the simple tunable indicating amplifiers to elaborate commercial receivers. The field of application of the 24 types is represented by area III. The frequency range goes up to 4600 Mc, the voltage sensitivity down below 1 μv.

The lower voltage limits stated hereinafter are specified for 1/10 of full-scale deflection of the meter. Lower voltages can be measured when a sacrifice in accuracy is permissible. The values given in parentheses indicate the lowest value marked on the scale.

A 1a Flat-response Voltmeters without Preamplification

BN 10 . . ., Type U . . .

The only R & S voltmeter operating on the principle described under 3. (voltage measurement by current measurement with series resistor) is the **Small Level Meter Type UPK** (BN 1061 or BN 1062). It contains a sensitive moving-coil meter in conjunction with a rectifier. The Type UPK is available for the frequency range 30 cps to 20 kc or 3 kc to 600 kc and is used for measurements on AF and CF telephone links. It has two sets of four measurement ranges, is calibrated in nepers or – 20 db to + 30 db (77 mv to 24.5 v). The switch-selected input impedances are 600 Ω and greater than 10 kΩ for the AF model and 75/150/174/600 Ω and greater than 4 kΩ for the CF model.

The four other voltmeters without preamplification are valve voltmeters with peak response and mostly with DC voltage amplification. The scales are calibrated in rms values. The **High-Voltage Electronic Voltmeter Type UDH** (BN 10331) has a measurement range of 120 v (50 v) to 1.8/7/35 kv (50 kc to 30 Mc, see Fig. 2) and is used for measuring and monitoring transmitter systems. The input capacitance is less than 12 pf. The two **Electronic Multimeters Type URI** (BN 1050) and **Type URU** (BN 1080) are versatile and compact instruments for laboratory and field operation. In conjunction with a great variety of accessories, such as probes, multipliers, and insertion units, voltages between 0.15 v (0.1 v) and 2.5 kv can be measured in the frequency range 10 cps to 1500 Mc. Both instruments also permit DC voltage measurements from 30 mv (5 mv) to 30 kv and resistance measurements from 0.5 Ω to 3000 MΩ. The Type URI furthermore measures direct currents from 0.01 μa (0.002 μa) to 1 amp in 12 ranges and alternating currents from 200 μa (100 μa) to 1 amp.

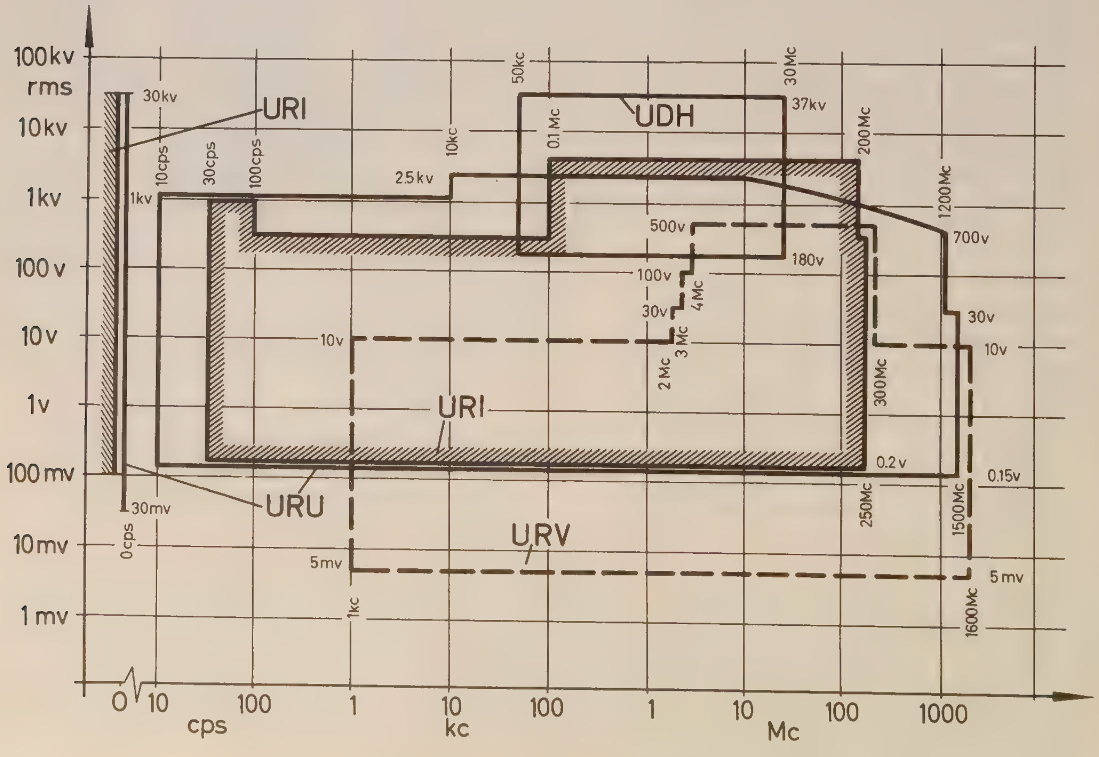


Fig. 2 The R & S voltmeters without preamplification

The **UHF Millivoltmeter Type URV** (BN 10910), having a particularly sensitive amplifier, extends the lower voltage limit down to 6 mv (5 mv). The lower frequency limit is 1 kc, as can be seen from Fig. 2. The instrument functions in conjunction with a probe or insertion unit. The input capacitance of the probe without multiplier is less than 2 pf, the VSWR of the insertion unit is less than 1.2.

Type	BN	Type of rectification	Voltage range	Frequency range
UPK	1061 1062	Linear full-wave average-responsive rectification crystal diode	77 mv – 24.5 v – 20 db – + 30 db – 2 nepers – + 3 nepers	30 cps – 20 kc or 3 kc – 600 kc
UDH	10331	Half-wave peak-responsive rectification valve diode	180 v (50 v) – 35 kv	50 kc – 30 Mc
URI	1050	Full-wave peak-responsive rectification valve diodes	0.1 v (0.02 v) – 30 kv 0.2 v (0.1 v) – 3 kv	0 cps 30 cps – 250 Mc
URU	1080	Half-wave peak-responsive rectification valve diode	30 mv (5 mv) – 30 kv 0.15 v (0.1 v) – 2.5 kv	0 cps 10 cps – 1500 Mc
URV	10910	Half-wave peak-responsive rectification crystal diode	6 mv (5 mv) – 500 v	1 kc – 1600 Mc

A 1b Flat-response Amplifier-rectifier Voltmeters

BN 120 . . ., Type UV . . .

The voltage and frequency ranges of the four R&S amplifier-rectifier valve voltmeters are shown in Fig. 3. The simplest instrument of this group is the **AF Millivoltmeter Type UVN** (BN 12001), which has a voltage range of from 100 µv (20 µv) to 300 v (10 cps to 100 kc) and finds use in the development, manufacture and monitoring of all kinds of audio-frequency systems. The **Microvoltmeter Type UVM** (BN 12011) has higher preamplification and permits measurements down to 30 µv (10 µv) for similar purposes as the Type UVN. The lower limit is definitely set by the noise voltage because of the bandwidth of 1 Mc. Both instruments, the Type UVN and the Type UVM, have an unbalanced high-impedance input and respectively one or two balanced inputs.

The **RF Millivoltmeter Type UVH** (BN 12021) and the **Video Millivoltmeter Type UVF** (BN 12015) cover relatively wide frequency ranges. While the Type UVH is generally preferred for measurements in the 30 cps to 30 Mc region, the Type UVF is specially designed for television (10 cps to 10 Mc) and has, in addition to the high-impedance input, a 75-Ω bridging type filter input. The lower voltage limit of both instruments is about 100 µv (see Fig. 3).

The amplifiers preceding the rectifiers of the four instruments here described may also be used separately, which is a great advantage, for example, for oscilloscopic display. With the exception of the AF Millivoltmeter Type UVN these instruments use full-wave peak-responsive rectification.

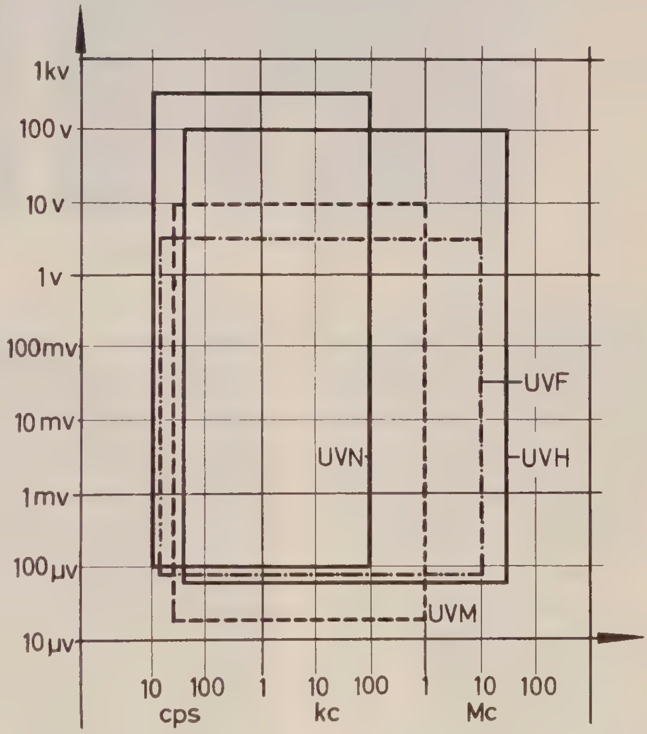


Fig. 3 The R & S voltmeters with preamplification

Type	BN	Voltage range	Frequency range	Type of rectification
UVN	12001	100 µv (20 µv) – 300 v	10 cps – 100 kc	Average-responsive rectification
UVM	12011	30 µv (10 µv) – 10 v	20 cps – 1 Mc	Full-wave peak-responsive rectification valve diodes
UVF	12015	100 µv (25 µv) – 3 v	10 cps – 10 Mc	Full-wave peak-responsive rectification valve diodes
UVH	12021	100 µv (25 µv) – 100 v	30 cps – 30 Mc	Full-wave peak-responsive rectification crystal diodes

To be continued.
Spa.

Did you know...

that the firm of Rohde & Schwarz had its anniversary this month?

Dr. Schwarz

Dr. Rohde

The site Tassiloplatz

that 28 years ago two vital, young and enterprising physicists, Dr. Rohde and Dr. Schwarz, turned a flat into a workshop in order to build RF measuring instruments. They called their small firm "Physikalisch-technisches Entwicklungslabor, Dr. Rohde, Dr. Schwarz"; that one year later this workshop employed a staff of 5 members. Among these was A. Habermann, today chief of the manufacturing department; that 4 years later, in 1937, a staff of 32 people moved to the new building of the firm;

that after 6 more years the building, although much enlarged, was insufficient. A new factory
was built on a site at Trausnitzstraße;
that an affiliated firm, the Meßgerätebau GmbH,
was founded in Memmingen in the course of the transfer necessary during the war;
that in 1946 the square-shaped emblem with the R and the S in it
was created. This emblem today represents the firm all over the world;
that the staff counted 400 members shortly after the end of the war;
that after the war the production of communications equipment was taken up in addition
to the measuring instruments;
that in 1954 a four-storey building for the production of transmitters was completed.

The building for transmitter production, Trausnitzstraße

The new building, Mühldorf

Did you know

that towards the end of last year the large extension building at the Trausnitzstraße-Mühldorfstraße could be occupied? It has a floor space of 11,000 m² and a volume of 45,000 m³; that the two factories in Munich together with the Meßgerätebau GmbH. count a staff of more than 2500 employees; that about 400 scientific papers have been published up to now by the physicists and engineers of Rohde & Schwarz; that Rohde & Schwarz is the biggest producer of RF measuring instruments in Europe?

The new building, Mühldorfstraße

Spa.

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